SOILS

FUNDAMENTALS

MONTANA DEPARTMENT

OF

TRANSPORTATION

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Road Design Fundamentals - Soils Course Outline

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II Problems Encountered During Construction
- A. Inadequate Soils Information
- B. Misinterpretation of Soils Data
- C. Design Criteria Errors

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FOREWORD

This booklet is meant to be used as a quick reference for most of the soils related questions that will be encountered by the road designer.

This booklet presents basic soils data and techniques used by the Montana Department of Transportation. There are other equally valid methods and the designer is encouraged to contact the Materials Bureau to clarify any documentation or methods which the designer is not familiar with.

The user is encouraged to provide comments and suggestions on how to improve this course and the course contents.

INTRODUCTION

NOTES

The road designer is involved with many soils and materials related design decisions which dramatically determine the success or failure of the overall project design. In the past, the MDT policies and procedures have relied almost exclusively on the Materials and Surfacing Design Sections to complete the soils data reviews and development of the surfacing typical section.

Many of these policies and procedures are in the process of being changed, requiring the road designer to become more actively involved in <u>all</u> design decisions. This "team design" concept is going to require all MDT personnel to understand the basic procedures for all sections. For example, the construction personnel are going to have to understand basic design procedures and the design personnel are going to have to understand basic construction procedures. This is also going to require the design sections to understand the basic concepts and procedures used by other design sections.

One of the areas of major concern is soils data and surfacing design. The average road designer has very little soils or surfacing design experience, and very little written reference material has been made available on this subject. This booklet is a composite of information received from the Materials and Construction Bureaus and represents the latest data available.

This booklet introduces the basic concepts within the soils and surfacing design areas. It is not intended to replace the materials or surfacing design personnel or their input into the road design process. This booklet will provide some insight into the soils and surfacing design decisions and make the road designer more comfortable being involved in the entire design process.

☞<u>Note</u>:At this point in time it is fair to point out that all current MDT policies and procedures are being reviewed and updated if necessary. New manuals and procedures are being published and the "team design" concept is being promoted throughout the MDT.

It is also important to recognize that the "system" is being analyzed, not individual

units or organizations. There is no intent to single out any individual policy or procedure, but to show some examples of the shortcomings of our previous policies and to solicit input for development of new policies which will incorporate the "design team" concept. The overall objective is to have a better design team - better educated, better informed, and better able to make the design decisions which will carry us into the 21st century.

To better understand the entire road design process, let us review some of the problems being encountered during construction that relate directly to soils and surfacing design. We will first review and discuss the problems being encountered and then, after reviewing the basic soils and surfacing design procedures, we will concentrate on solutions to these problems, and what role the road designer will play in implementation of these solutions.

I. PROBLEMS ENCOUNTERED DURING CONSTRUCTION

Many of the problems encountered in construction during the past several years are the result of MDT policies and procedures which are currently being analyzed. Some examples are being provided to illustrate the problems and show where improvements can be made. Generalizations are made for the sake of grouping problems and solutions together. Each specific project may have "specific" solutions, but if the designer is aware of how the general problem is solved, he/she can solve the specific problem much faster.

Problems encountered during construction can be grouped into several general categories which are listed below.

A. Inadequate Soils Information
B. Misinterpretation of Soils Data
C. Design Criteria Errors

A. INADEQUATE SOILS INFORMATION

Inadequate soils information can be caused by a number of things. One of the most common reasons is due to scope creep - where a project starts out as say an overlay and then ends up a full reconstruction project. This has happened on a good number of jobs. Unfortunately, the soils information from the overlay was used to design the reconstruction project and caused a great number of change orders due to extensive digouts and subexcavation.

Another common cause of inadequate soils information was that the sampling procedure used by the materials group called for samples at 0.5 mile intervals with no regard to cut or fill slopes or soils types. Due to the variable nature of soils, this caused a great deal of trouble when a subgrade was designed for a certain type of soil and a lesser quality soil was encountered. Another problem is that new materials personnel would not always get a complete soils survey as some of the necessary data would not be recorded or even sampled.

B. MISINTERPRETATION OF SOILS DATA

In many cases, soils data was not interpreted correctly by the materials personnel or by the road designer. Many times only a few samples were taken for soil support testing (R-values) and then this soil support data was used to represent soils of similar soils classes throughout the project. Due to the variability of R-values within soils classes, a physically unobtainable R-value was designed to support the surfacing section on many projects.

Another problem was identified when the earthwork was analyzed and the cuts and fills were not correctly taken into account in the subgrade design. Often times a sampling at 0.5 mile intervals was assumed to represent 0.25 mile back on stationing and 0.25 mile ahead on stationing. This simple assumption caused many subgrades to be built far below their designed support values, as the "representative soil" was not available in the 0.5 mile area.

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C. DESIGN CRITERIA ERRORS

At times the traffic patterns changed causing a roadway to see a dramatic increase in traffic volume, especially heavy truck traffic, which was not taken into account in determining the design life of the project.

Sometimes a horizontal line projection was made by the designer and it was "assumed" the soils information from 200 feet away would be the same. Or a grade was raised or lowered without regard to the soil profile or groundwater.

These are all very common problems which can occur in a variety of ways. We will concentrate on the solutions to these problems later in this booklet.

For now we want to concentrate on the basic soils and surfacing data and how this information is used by the materials personnel. As road designers, we must learn to interpret soils reports and the soils information we received for our projects. We must also determine if the soils information is adequate to complete our designs and if any special design considerations (such as subexcavation) are needed. We must learn to communicate with the materials personnel in their language and we must be willing to help them understand the road designer's jargon.

We will be concentrating on basic soils data and procedures for the next few sections of this booklet.

II. SOILS CLASSIFICATION

A. AASHTO Classification Method

The terms poor, good, and excellent have been used to describe everything from agricultural goods to soils. The terms gravel, sands, silts, and clays are more informative but do not have the same meanings to all people.

The soils engineer has come up with an identification system which describes the physical size (gradation) of the soil sample and its physical attributes (liquid limit, plasticity index, etc.). This method is called the AASHTO Classification Method and is used by the Montana Department of Transportation.

NOTES

In order to understand the AASHTO Classification Method we must define some key terms. These terms are listed in appendix A of this booklet.

We must also understand how the soil is graded according to size of particles within the soil. The soils engineer relies on special sized screens called sieves to determine the particle size. The sieves come in standard sizes and are based on the size of the square openings. The soils engineer is concerned mainly with the 3 inch sieve (75 mm), the number 10 sieve (10 openings per inch), the number 40 sieve, and the number 200 sieve for soils classifications.

In general the soil can be divided into five fractions as follows:

1. Boulders - Material retained on the 3 inch sieve.

2. Gravel - Material passing the 3 inch square openings and retained on the number 10 sieve.

3. Coarse Sand - Material passing the number 10 sieve and retained on the number 40 sieve.

4. Fine Sand - Material passing the number 40 sieve and retained on the number 200 sieve.

5. Combined clay and silt - Material passing the number 200 sieve.

Once the five fractions are determined, a weight percentage of each fraction can be determined. The weight percentages are the backbone to this AASHTO Soils Classification Method.

The AASHTO Soils Classification Method is summarized in the chart shown in appendix A.

The Montana Department of Transportation uses this test method and labels it MT-214 in the MDT Materials Manual.

Visual examinations can be performed in the field and a general idea as to the soils classification can be quickly determined. A visual identification process is also shown in appendix A.

Rarely do the soils encountered in nature exhibit only one soil fraction as most soils are a conglomeration

deposited over millions of years of activity.

Once the soil has been classified, general engineering properties can be assigned to each classification. The two basic engineering properties we are concerned with are the soil's ability to support a load (soil support capability) and the soils ability to allow water to pass or flow through it (permeability).

B. ENGINEERING PROPERTIES OF A SOIL

The soil support capability of a soil can be determined from resistance value testing or more commonly referred to as R-value testing. R-values range from -5 for the poorest soil to an R-value in the neighborhood of 85 for the best soils (usually gravel).
As a general trend, the lower R-values are associated with the higher soils class numbers. This trend is shown in appendix B. This is because the higher soils class numbers have a larger percentage of fine and very fine (minus 200) materials which act to "lubricate" the particle to particle interactions and do not allow the load to be carried on a soil matrix. The gravelly materials (A-1, A-2 soils classes) allow for particle on particle "bridging" action (soil matrix) which will carry a heavier load than the smaller particles.

☎Note: R-value testing requires expensive testing equipment (the Helena MDT Materials Lab has the only R-value testing equipment owned by the department) and a skilled operator. Unfortunately it can take several days, even up to a week before R-values are reported back to the field personnel.

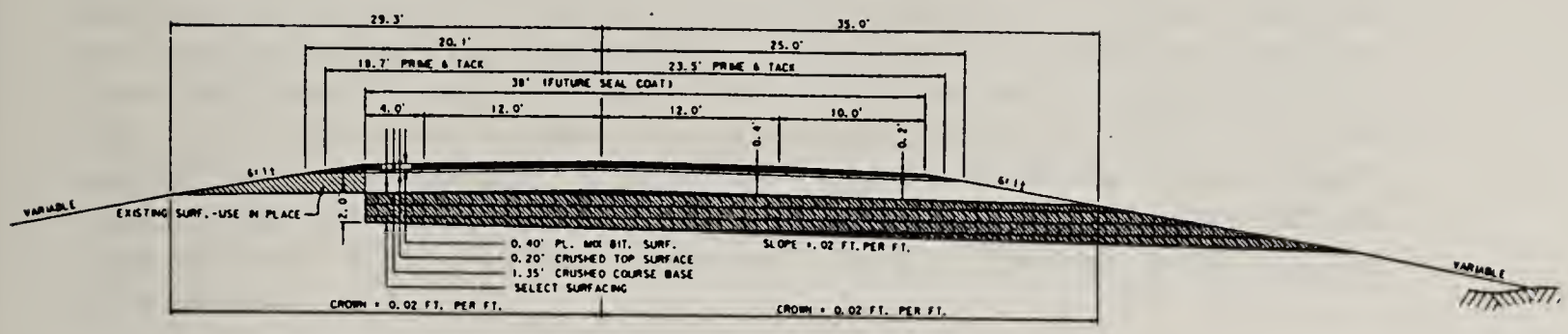
A general R-value range can be determined from the soils classification but due to the broad range of R-values in the classification it is imperative that a R-value test be completed for each sample. The results of R-value testing done by the MDT Materials Bureau is shown in appendix B.

The permeability of a soil can be measured in the laboratory, but is usually not done. The relative permeability of a soil is inversely proportional to the particle size. The smaller the particle size the less likely water is to permeate (flow) through the soil.

NOTES

TYPICAL SECTION NO. 4
DIGOUT SECTION IN FILL AREAS

(EASTBOUND)
(REVERSE THIS SECTION FOR WESTBOUND)



If a poor soil is encountered, with no water or contamination from fines present, simple excavation and backfill will correct the situation. Unfortunately, this is not usually the case, unless we are on top of a fill section. Most cut sections will require subexcavation drains or daylighting, and if economically feasible, separation fabric.

III. SOIL SURVEY DATA

The soil survey is requested by the road designer to get the necessary soils information. Lab form 111 is the backbone to most soils surveys. A copy of a completed form 111 is shown in appendix C.

The form 111 contains a lot of soils information that we should look at in depth and analyze from a materials and design viewpoint. The following items are shown on the form 111:

A. Date - Project soil conditions may change with time, so we need to make sure the soils data is current (within the last couple of years) or water tables, digout information, and rutting information may be out of date and of little use to us in the project design.

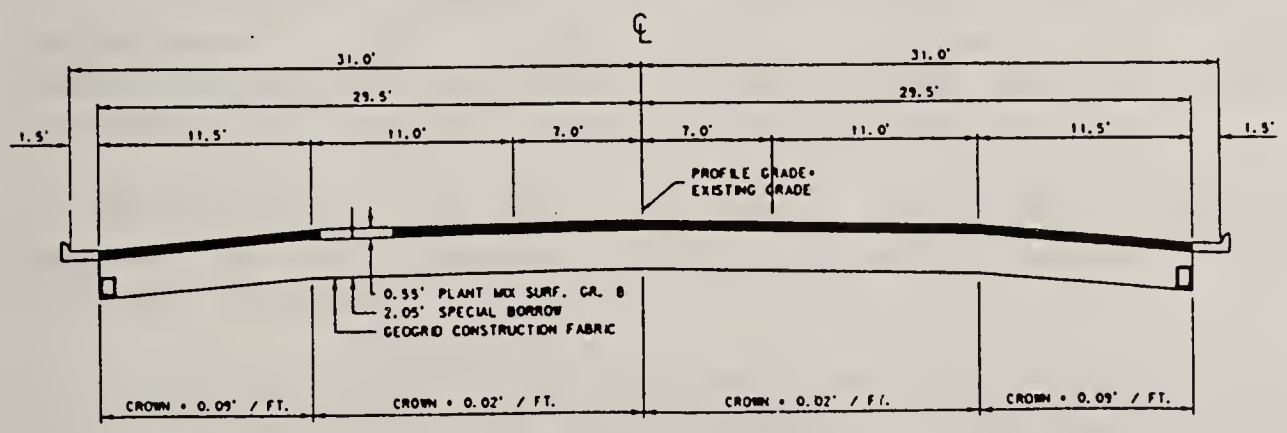
B. Location of Boring - Most soils surveys use the PTW or the staked centerline as a reference line. If a line projection exists, the soil sample location (new projected station and offset) needs to be updated to match the new projected centerline. If the line projection is far enough away from the staked centerline, additional samples should be taken to represent the new projected centerline.

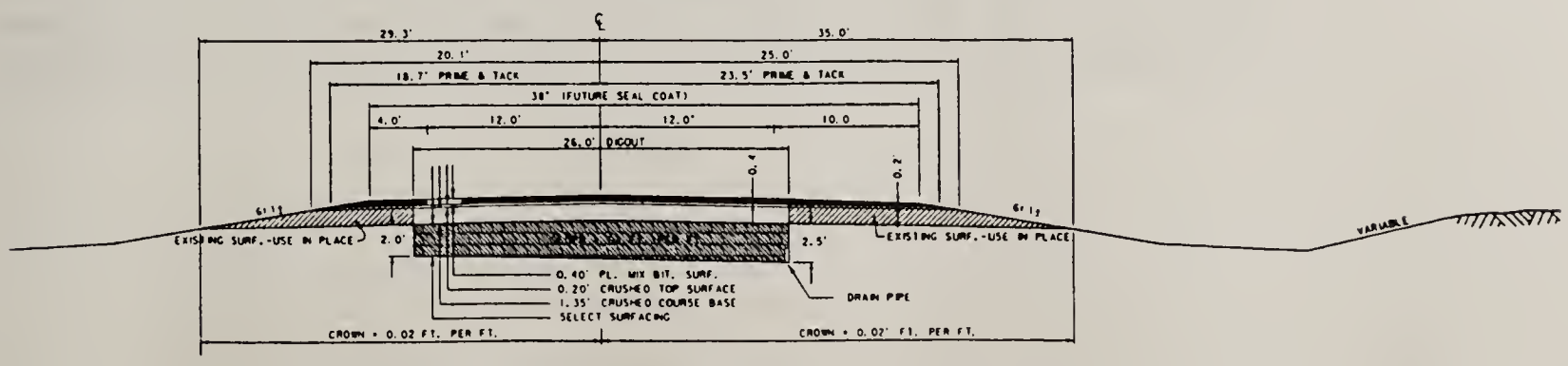
Permeability is especially important when we are subexcavating or providing digouts on a project. If we have a water problem or fine material is carried by water into newly placed subgrade material, the digout or subexcavation backfill will most likely become contaminated and loose its soil support capability. If this was the reason we subexcavated or dug out the material to begin with we must find a permanent solution to keep the backfill material from becoming saturated with water and/or contaminated with fine material.

Edge drains or a combination of edge drains and separation fabric as well as "day-lighting" the "bathtub section" are terms the soils engineer will use quite frequently.

What the soils engineer is trying to do is keep the fines from migrating (contaminating) the new backfill material. This is done by placing a separation fabric between the natural ground and the new backfill material and then placing good, free-draining, gravelly (permeable) backfill material on top of the separation fabric. If possible, the gravel extends out to the ditch line allowing any water to drain freely to the ditch. The fabric blocks the contaminates from filtering into the subgrade and gravity keeps the water from building up frost crystals in the fall and spring and causing frost heaves on the surface.

A variation of this method of drainage is to install edge drains in the subexcavation edges to drain the water. This is a compromise between "daylighting" the backfill section and may prove more economical than subexcavating to the ditch lines. This principle is illustrated in the following drawings:





C. Depth - The sampling depth is recorded from the top of the bored hole downward, with each soils classification layer shown.

D. Elevations - Elevations may be recorded from the benchmarks on a project but are more than likely left blank or referenced to the PTW Centerline. The elevations refer to the elevation of the groundline <u>at</u> the bore hole. If elevations are left blank or are referenced to the PTW centerline, the designer can correlate the elevation by use of the existing PTW profile or from cross section survey data.

(Note: The form 111 shown as an example has been modified. The elevation column is usually not shown, and a column that is labelled "representing station" is usually located in this position.)

E. Representing Station - This column will provide the designer with an idea as to what area the soil sample represents. Unfortunately, the materials crew will often split the distance between the last sample and the next sample and show this as the area the soil sample represents. <u>THIS IS INCORRECT</u>!! The soil sample represents that location only. It is up to the designer and soils engineer to determine the area the sample represents, through more testing and field observations. (More on this subject later.)

F. Soils Class - The entire boring may go through several soils classes. The depth of each different soils class is recorded and a sample taken back to the lab for soils classification.

G. Liquid Limit (LL) - The liquid limit is determined for each soil class for class identification purposes.

H. Plasticity Index (PI) - The plasticity index is determined for each soil class for class identification purposes. The higher the PI value - The greater the amount of clay in the sample.

I. Gradation - 10 mesh, 40 mesh, 200 mesh - Show the percent weight <u>passing</u> on the standard number 10, 40, and 200 sieves.

J. Specific Gravity / In-Place Density - This column is a recordation of the sample's in-place density, usually in pounds per cubic foot. If the specific gravity is given it can be converted to a density by

multiplying by the density of water (62.4 pounds/cubic foot).

K. Maximum Dry Density - The maximum dry density must be obtained from a proctor test. Very few labs run this test anymore, so this column is usually left blank. (More on this subject later.)

L. Percent Natural Moisture - This is the moisture, by weight comparison, to the dry soil particles. For example, 25% natural moisture is 25 pounds of water with 100 pounds of dry soil.

M. Percent Optimum Moisture - The optimum moisture must be determined from a proctor test. Very few labs run the proctor test anymore, so this column is usually left blank. (More on this subject later.)

N. Depth of Water Table - This is the depth, from top of the bore hole, to the water table. Recognize that the water table usually fluctuates with the time of year. The water table is usually at its highest at the end of irrigation season (July or August) in irrigated areas, and may be at its lowest in July or August in non-irrigated areas. Ask the soils engineer or lab personnel for their help in determining the highwater table.

O. R-Value - This is the R-value obtained for this particular soil sample. It is for this soil sample only and cannot be used for other similar soil classes due to the variability of the R-values within a soils class. Be aware and question, 50 reported R-values on the form 111 with only 10 R-values run in the lab. (More on this subject later.)

Additional items from a soils survey can be obtained if requested:

A. Corrosive Soils - Samples should be taken at the culvert locations to determine if the soil will be corrosive to the culvert materials. Also the source of the fill material should be tested if the culvert will receive fill over it.

B. Culvert Conditions - Ask the materials personnel to review all existing culverts (in an overlay situation) for corrosion. Reuse only very good culverts. Slight corrosion now is a good indicator that the culvert will not last the roadway design life.

NOTES

C. Digout and Subexcavation - If requested, the materials group will specify location, depth, and width for digout and subexcavation areas. Also if requested, the backfill material can be specified by the materials group.

D. Surfacing Condition - If requested, the materials group will obtain information on rutting, maintenance patching, plant mix surface cracking, and other surface condition items.

E. Other items - Land slide areas, surface water (springs), eroded areas, and other physical features can be located by the materials group. PMS Cores for stripping analysis and samples for PMS recycle mix design are also items which can be requested. Possible hazardous waste sites (such as underground tanks) are another item which can be located by the materials personnel. This list is endless, but must be "tailored" to the specific project.

IV. SOILS SURVEY REQUEST

As designers, we need to be able to interpret the soils data we receive. More importantly we must be able to request all the soils data we need, in one request if possible, and then completely interpret and incorporate this data into our design.

It is very time consuming and frustrating to the materials personnel to travel to a project location several times to retrieve soils data which could have been retrieved in one trip if the initial soils survey request had been thoroughly documented. Each time the materials personnel return to a project site they must relocate centerline and, if necessary, place traffic control devices to complete the sample retrieval. This duplicated effort is very costly and may place the materials personnel at risk from the traffic on the project.

Sometimes on a new construction or reconstruction we do not know what our vertical alignment is going to look like, but we have a good idea about the horizontal alignment. We can send the materials personnel out with the preliminary horizontal alignment to get our soils data. When we receive the soils data back from the field, and we receive our field survey data, we can design the vertical alignment. At this point, we must determine if the

soils data is adequate. If it is not adequate, we must request additional soils data as soon as possible so the materials personnel can schedule their work and so our design can continue when the soils data is returned to us.

For example, if the initial soil survey gave us a 20 foot bore hole and our cut is now 30 feet, we should request additional soils information for the area from 20 feet to 30 feet to determine what type of material exists or if we will encounter groundwater. It is important for us to review the initial soils information as well as our field survey information and request additional data in a timely fashion if it is needed.

A soils survey checklist is supplied in appendix C for a new construction or reconstruction project and for an overlay project. These checklists are very helpful in putting the initial survey request together.

V. SURFACING DESIGN

The Surfacing Design Unit works within the Materials Bureau to develop surfacing typical sections. The surfacing designer looks at three major design criteria:

1. Subgrade R-Values
2. Design Life
3. Traffic Data

Let's look at each factor in detail:

1. SUBGRADE R-VALUES

The subgrade R-value that is used for the design is based on the 85th percentile R-value for the typical section area. Different typical sections will be developed for subgrades which exhibit radically different R-values.

The surfacing designer can save a substantial quantity of materials, and ultimately money, if he correctly groups the subgrade sections and matches the typical section to the subgrade. The surfacing designer could look at the entire project and design one typical section for the entire project length, but many sections would be grossly over designed and valuable

resources would be expended needlessly.

The surfacing designer tries to produce a minimum number of typical sections (to satisfy construction and design considerations) while minimizing the total surfacing material quantities. This task can become very time consuming as a large number of design situations must be analyzed and the optimum solution extracted.

The surfacing designer looks at only the top 2 feet of subgrade material in the typical section design. If borrow is required or if the design calls for selective grading the top two feet of subgrade material can be greatly improved by specifying a higher R-value soil. This can dramatically reduce the typical section thickness and reduce the project cost if the borrow or selective grading can economically be incorporated into the project design. This design option should be explored in detail on every project as it can literally save the department millions of dollars each year if implemented properly.

In an overlay design situation, the existing subgrade is sampled and the top two feet has an R-value test run on it. The surfacing designer determines the existing subgrade 85th percentile R-value and then reviews the existing surfacing section to develop an overlay thickness. Digouts, if used as a subgrade improvement tool, can dramatically reduce an overlay thickness in some areas and can prove to be cost savers if properly used.

Unless the project is a thin lift overlay, projects with poor subgrades and minimal existing surfacing are going to be recommended for reconstruction. If reconstruction is required in 25% of the project, it will be upgraded to full reconstruction for the entire project length (new MDT Geometric Design Standards, approved December 4, 1992).

2. DESIGN LIFE

The normal surfacing design life is 20 years for new construction and most overlays. A lesser design life may be approved in some circumstances.

It is important to point out that the roadway surfacing may or may not last 20 years as this actually corresponds to a number of vehicle loadings

projected to occur in a 20 year time period given the present traffic and the projected growth. If the projected growth is higher than the value the designer used, the roadway will experience increased loading and probably will not last the 20 year timespan it was designed for. In fact, it will reach the 20 year loading in say 15 years. It must be remembered the roadway DID hold up for the design life (number of loadings) but that it happened in a LESSER TIMESPAN than anticipated.

3. TRAFFIC DATA

Current traffic data is obtained from field collected data. The traffic data is then projected over the design life taking into account the projected growth.

Note: This growth is an exponential growth and it is expressed by the following formula:

Future Value = (Present Value) X (1 + G)^n

where: G = Growth factor in percent growth
(i.e. 4% = 0.04)
n = number of years in the design life

So if we wish to find the ADT on a certain roadway in 20 years, we need to determine the present ADT and then determine the growth factor. For our example:

Assume: Present ADT = 2,000 vehicles/day
Growth Factor = G = 2% = 0.02

Then the future ADT (in 20 years) is :

Future ADT = (Present ADT) X (1 + 0.02)^20
= (2,000) X (1.485947)
= 2,972 vehicles/day

In addition to the increased vehicles the surfacing designer must take into account several other factors:

A. 18 Kip ESALS - The traffic data supplied to the surfacing designer also has 18,000 pound Equivalent Single Axle Loads, and this is the traffic data the surfacing designer actually uses. Also the design life is correlated to a total number of 18 Kip ESALS for the entire design life.

NOTES

B. Other Factors - Other factors such as a loading factor takes into account the type of roadway (Primary, Interstate, etc.). A serviceability factor takes into account the region of the country and the freeze-thaw cycles. High volume, multi-lane facilities must take into account the fact that not all vehicles travel in the driving lane at all times (some are in the passing lanes). The last major factor is a directional factor - not all traffic goes and comes on the same road. For design purposes the directional factor is usually taken at 50% (50% traffic counted in one direction and 50% traffic in the opposite direction).

The surfacing designer takes all this into account when the typical section is developed and sent on to the road designer. This procedure is outlined in the "MDT Pavement Design Manual, 1991."

Let's look at an example to illustrate this design procedure.

Given: New Construction - Interstate
Serviceability and Regional factor = 2.5
Design life = 20 years
1990 ADT = 1680 vehicles/day
Growth Rate = 1%
Lane Design Factor = 100%
Directional Factor = 50%
Subgrade R-value (85th percentile) = 10

Find: A typical section which will meet MDT design criteria.

SOLUTION:

1. Find 2010 ADT (20 year design):

2010 ADT = (1990 ADT) X (1 + 0.01)^20
= (1680) X (1.22019)
2010 ADT = 2050 vehicles/day

2. Find mean year ADT:

This procedure is shown on data sheet number 1 in appendix D.

☞Note: Detailed traffic data must be obtained for this type of analysis. In general the mean year is the midpoint of the design life and

the mean ADT is determined by obtaining the 1990 ADT and 2010 ADT for each vehicle category and determining the mean (or average) of these two values. The sum of all the vehicle type mean ADT is the mean year ADT.

3. Find Average Daily 18 Kip EAL For A 20 Year Design Life:

Each vehicle category must be looked at separately and then the sum of the mean year ADL (Average Daily Load) is determined.

We will show this calculation for one vehicle type - the 5 axle truck/full trailer vehicle class.

A. Find Current ADT For This Vehicle Type:

Given: % vehicle type = 0.2%; 1990 ADT = 1680

current ADT = (total 1990 ADT)X(% vehicle type)
= (1680) X (0.002)
= 3.36 vehicles

B. Find Design Year ADT (2010 ADT) for this vehicle type:

Given: growth rate = 1%
current ADT = 3.36 vehicles

design year ADT (2010) = (current (1990) ADT) X
(1 + 0.01)^20
= (3.36 vehicles)X(1.22019)
= 4.10 vehicles

C. Find Mean Year ADT For This Vehicle Type:

$$\text{mean year ADT} = \frac{\text{1990 ADT + 2010 ADT}}{2}$$

$$= \frac{3.36 + 4.10}{2}$$

= 3.73 vehicles
RND = 3.7 vehicles

D. Find Directional ADT For This Vehicle Type:

Given: directional factor = 50%

directional (mean yr) ADT = (mean yr ADT) X
(directional factor)
= (3.73)X(0.50)
= 1.865

RND = 1.9 vehicles

E. Find Design Lane ADT For This Vehicle Type:
Given: lane design factor = 100%

design lane ADT = (directional ADT) X
(lane design factor)
= (1.9) X (1.00)
= 1.9 vehicles

F. Find 18 Kip Equivalent Rate Factor:
Given: 5 axle truck with the trailer full is equivalent to 2.102~18,000 pound single axle loads.

Note: See appendix D for a graphical representation of this equivalent rate factor.

G. Find Mean Year ADL (Average Daily Load) For This Vehicle Type:

mean year ADL = (design lane ADL) X
(18 Kip equivalent load factor)
= (1.865) X (2.102)
= 3.92 18-Kip Equiv. Axle Loads

H. Adding all the vehicle type mean year ADL's produces the average daily 18-Kip EAL for a 20 year design life, in this case 188.07~18-Kip EAL.

I. The design life total 18-Kip Equivalent Axle Loads is determined by taking the daily axle load for 20 years:

(188.07) X (20 years x 365 days/yr)
= 1,372,886 18-Kip Equivalent Axle Loads

4. Determine Weighted Structural Number From The Nomograph In Appendix D:
Given: R-value = 10
Regional Factor = 2.5
Interstate Design
188.07 18 Kip EALS

From the nomograph, weighted structural number is 4.3.

5. From Table 3-1, Minimum Design Criteria, in Appendix D, we find:

Min. Surfacing Course	= 0.40 ft.	Plant Mix Surf.
Min. Leveling Course	= 0.20 ft.	Crushed Gravel
Min. Base Course	= 0.35 ft.	Asphalt Base
	= 0.35 ft.	Treated Soils
	= 0.50 ft.	Crushed Gravel

Normally, we will match the weighted structural number to the design typical section by using the minimum plant mix surfacing, minimum leveling course (usually crushed top surfacing), and then get the remaining surfacing strength from the base course (usually crushed base course gravel).

If the typical section becomes too thick, then our next course of action is usually to improve the base with cement treated base or lime stabilization. The next course of action is to use a plant mix (asphalt) base and/or increase the plant mix surfacing thickness.

Now we need to introduce the structural coefficients for each surfacing material. These coefficients are shown in Table 3-2 in appendix D.

Let us find the STRUCTURAL NUMBER (Sn) provided by the minimum plant mix surfacing and the minimum crushed top surfacing:

A.) 0.40′ PMS X (4.0/1 ft. PMS) = 1.60 Sn
B.) 0.20′ CTS X (1.4/1 ft. CTS) = 0.28 Sn
Total = 1.88 Sn

Given our required Sn = 4.30, our crushed base course will need to supply

4.30 - 1.88 = 2.42 Sn

Determine Thickness of CBC Required:
(we will use 1 1/2" max. CBC here)

2.42 Sn X (1 ft. CBC/1.40 Sn) = 1.72 ft.
therefore use 1.75 ft. CBC

NOTES

Our typical section now looks like this:

0.40 ft. Plant Mix Surfacing (PMS)
0.20 ft. Crushed Top Surfacing (CTS)
1.75 ft. Crushed Base Course (CBC)
2.35 ft. Total Thickness

Overlays are designed in a similar fashion, except the existing surfacing material is given a reduced strength value based on the condition of the plant mix surfacing. Table 5-2 in appendix D shows the reduction factor used for the given plant mix surfacing condition.

Although a reduction factor is not given to the gravel surfacing, it may become contaminated with fines and have a lesser strength. This reduced gravel strength usually appears as distress (cracking) in the plant mix surfacing. The reduction factor shown in Table 5-2 essentially compensates for reduced plant mix surfacing strength and reduced gravel strength, so a separate reduction factor for the existing gravel is not usually applied.

On lower volume roads that receive gravel surfacing, an aggregate thickness chart is used to design the gravel thickness based on the traffic level and the subgrade R-value. This chart is shown in appendix D, along with a table of the gravel gradation requirements.

The surfacing designer also looks at Road Rater (non-destructive load testing on the roadway) Data and several other surfacing design methods in conjunction with the AASHTO Design Method. These combined methods are used to produce the final typical section design returned to the road designer.

NOTE: It is still necessary for the road designer to request typical sections for all projects from the surfacing design unit. This procedure assures the proper typical section design, with all design considerations being taken into account.

The procedure we just witnessed has been simplified for this booklet. A more thorough analysis would have been made had the Surfacing Design Section undertaken the process.

NOTES

SURFACING TYPICAL SECTION REQUESTS

Surfacing typical sections are requested through the Materials Engineer. It is very important that the road designer send the latest traffic data to the surfacing design unit. This is done as an attachment to your request memo.

The subgrade R-values need to be completed before the surfacing design unit can proceed with the typical section design. The road designer is responsible to see that all this information gets to the Surfacing Design Unit. The Surfacing Design Unit does not need a copy of the R-value information submitted with your request - they will receive a copy from within the Materials Bureau.

A sample surfacing typical section request memo is shown in appendix D for your use.

VI. Soils Related Problem Solutions

We previously identified 3 major soils related problems:

A. Inadequate Soils Information
B. Misinterpretation Of Soils Data
C. Design Criteria Errors

We have also acquired some basic knowledge of soils surveys, surfacing design, and now we can apply this information towards solving or at least limiting the impact of these soils related problems in our road designs. Let's look at each of the above situations in some detail.

A. Inadequate Soils Information

We looked at the problem of scope creep - the project was nominated as an overlay and now is a reconstruction project. Several things are being contemplated to improve this problem.

One consideration is to redesign the nomination process so projects can be nominated based on budget amounts and not the type of work. This will eliminate the reconstruction project being nominated as an overlay because only overlay money is available. This is also going to require that more soils work be done prior to the nomination so the type of project and

surfacing thickness can be determined, prior to the nomination process. This will also allow the nomination cost to be more accurate in comparison with the final construction cost.

It is beyond the road designer's control to change the nomination process. The road designer must be aware that this problem exists and do everything possible to make sure additional soils data is obtained to adequately design the reconstruction project.

The second problem cited was incomplete soils surveys due to sampling procedure problems or incomplete soils surveys. This is going to require cooperation and communications between the materials personnel and the road designer. The road designer is now required to plot the soils profile and soils data on the project profile (per an April, 1993 memo from the Preconstruction Engineer).

If the road designer does not have enough soils data when the plots are put on the profile, it is his/her responsibility to request additional soils information. The designer then should be very specific as to locations, depths, and any other necessary information. Contact the materials personnel if help is needed in determining the this data request. Most of these problems are from the bore hole not being deep enough in cut areas or cut sections not having enough samples to determine representative soils classifications.

The materials group is also reviewing their sampling procedures and may be implementing better guidelines for their personnel to follow. The most important thing to remember is that good communications between the road designer and the materials group will identify problems <u>early</u> in the design phase.

In-place densities and maximum dry density tests will need to be performed to allow design personnel to calculate shrink factors. The mass diagram, as a design tool, will also be reviewed in more depth in future design classes.

B. <u>Misinterpretation Of Soils Data:</u>

Misinterpretation of soils data is still a major problem. We need to better educate our road design personnel how to interpret the soils data. This

course is a start that needs to be explored in further detail. The road designer should not hesitate to discuss his questions with materials personnel as this is one way to help the road designer understand the materials personnel's point of view. It will also allow the materials personnel to become more familiar with the road designer's needs and will help the materials personnel understand the road design process, thereby fostering our team design concept.

Misinterpretation of data is still a problem when it comes to using similar soils classes for similar R-values. We have pointed out that each R-value represents only that soil sample. Our materials and design personnel are now aware of this problem and will begin to process R-values for each soils sample submitted. This is going to increase the soils survey cost and will cause some additional work for the Helena testing personnel, but it is critical to improving our knowledge of the existing soil conditions and ultimately improving our designs.

The materials and design personnel are also aware that soil sampling at 0.5 mile intervals is not the usual practice for reconstruction projects. Also they are now informed to get samples representative of the area and to take enough samples to accurately represent the area.

The construction and materials personnel are now monitoring the subgrade construction more closely and are sampling the top 2 feet of constructed subgrades to assure the design R-values are being met. Any subgrade problems are being addressed quickly during construction and are becoming less frequent due to better road design, materials, and construction interaction. This interaction still requires improvement and we still have a long ways to go in truly having a design team in all areas of the MDT.

C. Design Criteria Errors

Design criteria errors are becoming less frequent but still need to be addressed. Traffic patterns and growth trends are being more accurately monitored and predicted. New developments (shopping malls, subdivisions, mines, etc.) are being asked by county, city, and state agencies to provide improved traffic facilities as part of their new development.

Horizontal and vertical line projections still cause the majority of our problems. It is imperative that the road designer inform all concerned parties (Right-Of-Way, Materials, Utilities, Traffic, etc.) when the alignment is shifted. This responsibility falls directly on the road designer's shoulders and requires the road designer to inform all concerned parties as soon as possible of a line projection or grade change.

Road designers must communicate with the materials personnel to identify problem sites. Hazardous underground storage tanks, groundwater problems, digout areas, and other items are best located by the materials personnel. Road designers should not hesitate to use the materials personnel as an "extra set of eyes" for the project. When problems are identified, then the specialty design units should be contacted for assistance. For instance, the Environmental and Hazardous Waste Bureau should be contacted if underground storage tanks are located by survey or materials personnel. Geotechnical should be consulted on groundwater problems. Use the MDT team to its fullest capacity to help you design the job.

COURSE SUMMARY

The road designer is being asked to become involved more completely with the entire design process. At first this request seems formidable, and it is. But with increased communications within our MDT sections and more specific training, the road designer will find these responsibilities less challenging as each "design hurdle" is cleared.

This is also going to make the road designer a more "complete designer" with the major emphasis still on road design. It is also going to help the road designer to put the complete design jigsaw puzzle together, from start to finish, and to identify problem pieces which don't seem to fit.

Good communications, an open mind to new ideas and methods, and some insight into other design sections will allow the road designer the ability to oversee the total design of his or her project. This will improve the plans reaching the construction personnel and ultimately lower the project costs, thereby freeing more tax dollars for more roads, better design equipment, and potentially a financial reward ($$!) for the more deserving designer and all MDT employees.

APPENDIX A - SOILS TERMS AND AASHTO CLASSIFICATIONS

The following soils glossary has been developed by the Materials Bureau to assist the designer with understanding basic soils terminology.

The AASHTO Classification chart is shown for quick reference as is the field identification sheet.

GLOSSARY

ATTERBERG LIMITS.--Four states of soil consistency as defined by the liquid limit, plastic limit, and shrinkage limit tests.

CAPILLARY ACTION (CAPILLARITY).--The rise or movement of water in the interstices of a soil due to capillary forces.

CAPILLARY WATER.--Water subject to the influence of capillary action.

COHESION.--All of the shear strength of a soil not due to friction. It is the portion of the shear strength of a soil indicated by the "c" in Coulomb's equation, $s = c + p \tan \phi$.

COMPACTION.--Densification due almost entirely to the expulsion of air from the soil mass by mechanical manipulation.

COMPRESSIBILITY.--Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

CONSOLIDATION.--The gradual reduction in volume of a soil mass resulting from an increase in compressive stress.

DEFLECTION.--The amount of downward vertical movement of a surface due to the application of a load to the surface.

ELASTICITY.--Ability of a soil to return to its original shape after having been deformed by a load for a short period of time.

FROST SUSCEPTIBLE.--Soil susceptible to freezing because of a water table close enough to the frost line to feed growing ice lenses and characteristics favorable to the rapid movement of capillary water upward from the water table.

LIQUID LIMIT.--The water content, as determined by the standard liquid limit test, at which a soil passes from a plastic to a liquid state.

MAXIMUM DENSITY (MAXIMUM UNIT WEIGHT).--The dry unit weight defined by the peak of a compaction curve.

MOISTURE CONTENT.--See Water Content.

OPTIMUM MOISTURE CONTENT.--The water content at which a soil can be compacted to the maximum dry unit weight by a given compactive effort.

PEDOLOGY.--The science that treats of soils, including their nature, properties, formation, functioning, behavior and response to use and management.

PERMEABILITY.--The rate at which water will flow or pass through the pores of a soil.

PLASTICITY.--The property of a soil that allows it to be deformed beyond the point of recovery without cracking or appreciable volume change.

PLASTICITY INDEX.--The numerical difference between the liquid limit and the plastic limit.

PLASTIC LIMIT.--The lowest water content, as determined by the standard plastic limit test, at which a soil remains plastic.

POROSITY.--The ratio, usually expressed as a percentage, of the volume of voids of a given soil mass to the total volume of the soil mass.

REBOUND DEFLECTION.--The amount of vertical rebound of a surface that occurs when a load is removed from the surface.

RESIDUAL DEFLECTION.--Difference between original and final elevations of a surface resulting from the application and removal of one or more loads to and from the surface.

SHEAR STRENGTH.--The maximum resistance of a soil to shearing stresses. It is the result of friction between the particles, and cohesion.

SHRINKAGE AND SWELL.--Volume change due to build-up and release of capillary tensile stresses within the soil's pore water.

SOIL.--Any earthen material, excluding bed rock, composed of loosely bound mineral grains of various sizes and shapes, organic material, water and gases.

SOIL HORIZON.--One of the layers of the soil profile, distinguished principally by its texture, color, structure, and chemical content.

"A" HORIZON.--The uppermost layer of a soil profile from which inorganic colloids and other soluble

materials have been leached. Usually contains remnants of organic life.

"B" HORIZON.--The layer of a soil profile in which material leached from the overlying "A" horizon is accumulated.

"C" HORIZON.--Undisturbed parent material from which the overlying soil profile has been developed.

"D" LAYER.--Any layer underlying the "C" horizon, or the "B" if no "C" is present, which is unlike the horizon above it.

SOIL PROFILE.--Vertical section of a soil, showing the nature and sequence of the various layers, as developed by deposition or weathering, or both.

SOIL STRUCTURE.--The arrangement and state of aggregation of soil particles in a soil mass.

SOIL TEXTURE (GRAIN SIZE DISTRIBUTION, GRADUATION).--Proportion of a material of each grain size present in a given soil.

VOID RATIO.--The ratio of the volume of void space to the volume of solid particles in a given soil mass.

WATER CONTENT (MOISTURE CONTENT).--The ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles.

KHN:Q:MT:89.cg

TABLE 14–2. American Association of State Highway and Transportation Officials Classification of Soils and Soil-Aggregate Mixtures, with Suggested Subgroups

AASHTO Designation M145											
General Classification	*Granular Materials (35% or Less Passing No. 200 Sieve)*							*Silt-Clay Materials (More Than 35% Passing No. 200 Sieve)*			
	A-1			*A-2*							*A-7*
*Group Classification**	*A-1-a*	*A-1-b*	*A-3*	*A-2-4*	*A-2-5*	*A-2-6*	*A-2-7*	*A-4*	*A-5*	*A-6*	*A-7-5, A-7-6*
Sieve analysis: % passing:											
No. 10 (2.00 mm)	50 max.										
No. 40 (0.425 mm)	30 max.	50 max.	51 min.								
No. 200 (0.075 mm)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40 (0.425 mm)											
Liquid limit				40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.†
Group index‡	0		0	0		4 max.		8 max.	12 max.	16 max.	20 max.
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

**Classification procedure:* With required test data available, proceed from left to right on above chart, and correct group will be found by process of elimination. The first group from the left into which the test data will fit is the correct classification.

†Plasticity index of *A*-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of *A*-7-6 subgroup is greater than LL minus 30.

‡See group index formula for method of calculation.

FROM "HIGHWAY ENGINEERING" BY OGLESBY AND HICKS, FOURTH EDITION

VISUAL & MANUAL IDENTIFICATION OF SOILS

GRAVEL - Identified by particle size. The particles may have an angular, rounded, or subrounded shape. Gravel size particles usually occur in varying combinations with other particle sizes.

SAND - Identified by particle size. Gritty grains that can easily be seen and felt. No plasticity or cohesion. Size ranges between gravel and silt. Material will pass the Number 10 U.S. standard sieve and be retained on the Number 200 U.S. Standard sieve.

SILT - Identified by behavior. Fines that have no plasticity. May be rolled into a thread but will easily crumble. Has no cohesion. When dry, can be easily broken down by hand into powdery form. Material will pass a Number 200 U.S. standard sieve.

1. Nonplastic
2. Powders easily when dry
3. Dries rapidly
4. Free water appears when shaken
5. Wire cut surface - rough

CLAY - Identified by behavior. Fines that are plastic and cohesive when in a moist or wet state. Can be rolled into thin thread that will not crumble. When dry, forms hard lumps which cannot be readily broken by hand. Clay is often encountered in combination with other soil sizes. If a sample exhibits plasticity or cohesion it contains clay. The amount of clay can be related to the degree of plasticity or cohesiveness; the higher the clay content the greater the plasticity. This material passes the Number 200 U.S. standard sieve.

1. Plastic, acts like putty when moist and wet
2. High dry strength
3. Dries slowly - sticky
4. No free water when shaken
5. Wire cut surface - smooth

PEAT - Black or dark brown plant remains. The visible plant remains range from course fibers to finely divided organic material.

APPENDIX B - R-VALUE TESTING AND CORE LOGS

The R-value testing information has been compiled by the Materials Bureau over the past few years. It is a good source of information to correlate the soils class with the anticipated R-value range.

The core log is shown as an example of how the Geotechnical personnel will document the soils information that they obtain.

SOIL CLASS/R-VALUE

Soil Class	R-Value Range
A-1-a	50 - 85
A-1-b	50 - 75
A-3	50 - 75
A-2-4	10 - 45
A-2-6	-5 - 30
A-4	-5 - 50
A-5	-5 - 40
A-6	-5 - 30
A-7-5	-5 - 30
A-7-6	-5 - 20

These ranges of values are from tests on soils performed in the MDT Materials Bureau from throughout the state. A -5 (minus five) is the lowest value that is reported.

Lab Form 30
Revised 12-89

MONTANA DEPARTMENT OF HIGHWAYS

(Crew No.) 2nd Hole Drilled In 90

Boring No: 4-02-90 Project No: F 1-1117(65) Date: 2-23-90

Hole No: ---------- Project Name: Elk Hills - Lion Springs

Boring Location: Sta. 64+00 65' Rt. Q - 18' above subgrade

Legal Description: NE1/4, NW1/4, SE1/4 Sec. 30, T27N, R28W Purpose: Subsurface Investigation

Geotech: ---------- Driller: ----------

DEPTH	ELEV. 2384.8	LEGEND	SPT Core Rec. % RQD (xx)	DESCRIPTION OF MATERIALS	ADDITIONAL INFORMATION
0.0				GRAVEL - tan sandy gravel	
3.7					
4.8			2/2/2	SILT - very loose to loose tan sandy clayey silt with some gravel	
			2/4/4		▽ 12.5 24 hr. after drilling
13.4				▽ G.W.	
16.5			4/3/6		
			5/6/8	CLAY - stiff to very stiff, grey silty clay	
			9/10/13		40' of 8" Augers
29.0			26/50 (1.0)	SHALE - very hard dark grey shale	
			50R (0.4)		
39.0				Bottom of Hole	

'N' = SUM OF LAST TWO 6" DRIVES FOR SPT.
FOR 2/4/4 N=8

"LOOSE" FOR A SILT, SAND OR GRAVEL; MEDIUM STIFF FOR A CLAY

R = means refusal where the sampler after receiving 50 blows has failed to advance 6" to the next sampling increment.

(0.4) - the actual penetration of the sampler.

REC 70%

REC = % CORE RECOVERED FROM CORE RUN

ROD 35

ROD = ROCK QUALITY DESIGNATION = TOTAL LENGTH OF CORE PIECES LONGER THAN 4' DIVIDED BY TOTAL LENGTH OF RUN

Depth Scale: 1" = 10' No. Sample Boxes: 1

Depth to H_2O measured from ground surface: 13.4 No. Shelby Tubes: 0

PVC Pipe (ft.): 30

MONTANA CADD ****DATE**** ****TIME**** ****USER**** ****DESIGNATED SPECIFICATION****

APPENDIX C - FORM 111 AND SOILS CHECKLISTS

The following appendix contains a sample Form 111 that is used by the materials personnel to document the soils information obtained in the field.

Attached are some sample soils checklists. These checklists are examples and should be modified to fit the specific design situation.

Lab Form No. 111
Revised May 1989

Montana Department of Highways

Preconstruction Soil Survey Data

and Special Recommendations Relative to Subgrade and Road Surface Design

Project Number F23-1(15)33PE (CN 01514) Designation Volborg - North & South Length 14.70 Mi. County Custer Date 10-7-92

Submitted by Alan D. Clapp Title MLS 2

Clifford "Toby" Tennant
District Materials Supervisor

Arthur Anderson
District Engineering S.S.

Sample Number	1992 Date	Location of Boring	Depth	Elevations		Soil Class (MT 214)	LL	PI	10 Mesh	40 Mesh	200 Mesh	Specific Gravity	Maximum Dry Density	Percent Natural Moisture	Percent Optimum Moisture	Depth to Water Table	"R" Value (AASHTO T190)	
	3-23	MP 47.55 100' E. C.L.	0-18.0'		3070.12'	A-2-4(0)	NP	NP	100	99	25	2.538		13.9			60	R-1
			18.0-20.0'			A-6(17)	38	21	100	99	84	2.699		15.6				
	3-23	MP 47.41 100' E. C.L.	0-7.0'		3082.39'	A-6(10)	30	13	97	96	86	2.650		8.5			-5	R-9
			7.0'-15.0'			A-4(10)	NP	NP	100	99	42	2.673		6.9				

Remarks

MT-207

csc

PROJECT CHECKLIST

PROJECT NAME :_____

PROJECT NUMBER:_____

OVERLAY/OVERLAY AND WIDENING:

DESIGN ACTIVITY	STATUS
1.) REQUEST SOILS SURVEY FROM DISTRICT: (standard form 111 items)	
A.) ELEVATIONS TO BORING HOLES	_____
B.) SOILS CLASSIFICATIONS	_____
C.) LIQUID LIMIT/PLASTICITY INDEX	_____
D.) GRADATIONS (10,40,200 MESH)	_____
E.) IN-PLACE DENSITIES	_____
F.) MAXIMUM DRY DENSITIES	_____
G.) PERCENT NATURAL MOISTURE	_____
H.) PERCENT OPTIMUM MOISTURE	_____
I.) DEPTH TO WATER TABLE	_____
J.) R-VALUES	_____
2.) ADDITIONAL SOILS INFORMATION FROM DISTRICT:	
A.) CORROSIVE SOILS TESTING FOR CULVERTS	_____
B.) DIGOUT EXCAVATION RECOMMENDATIONS (LOCATION, DEPTH, WIDTH)	_____
C.) DIGOUT BACKFILL REQUIREMENTS	_____
D.) EXISTING CULVERT CONDITION	_____
E.) EXISTING SURFACING CONDITIONS:	
1. RUTTING MEASUREMENTS	_____
2. MAINT. PATCH LOCATIONS	_____
3. PLANT MIX SURFACING CRACKING	_____
4. CORES FOR STRIPPING ANALYSIS	_____
E.) OTHER ITEMS (LANDSLIDE AREAS, SPRINGS, EROSION PROBLEMS, ETC.):	
_____	_____
_____	_____
_____	_____
3.) REQUEST ADDITIONAL SOILS INFORMATION FROM HELENA CORE DRILL, GEOTECHNICAL, ETC.:	
_____	_____
_____	_____
_____	_____

sak:soilover

PROJECT CHECKLIST

PROJECT NAME :_____

PROJECT NUMBER:_____

NEW CONSTRUCTION/RECONSTRUCTION:

DESIGN ACTIVITY	STATUS
1.) REQUEST SOILS SURVEY FROM DISTRICT: (standard form 111 items)	
A.) ELEVATIONS TO BORING HOLES	_____
B.) SOILS CLASSIFICATIONS	_____
C.) LIQUID LIMIT/PLASTICITY INDEX	_____
D.) GRADATIONS (10,40,200 MESH)	_____
E.) IN-PLACE DENSITIES	_____
F.) MAXIMUM DRY DENSITIES	_____
G.) PERCENT NATURAL MOISTURE	_____
H.) PERCENT OPTIMUM MOISTURE	_____
I.) DEPTH TO WATER TABLE	_____
J.) R-VALUES	_____
2.) ADDITIONAL SOILS INFORMATION FROM DISTRICT:	
A.) CORROSIVE SOILS TESTING FOR CULVERTS	_____
B.) SUBEXCAVATION RECOMMENDATIONS (LOCATION, DEPTH, WIDTH)	_____
C.) SUBEXCAVATION BACKFILL REQUIREMENTS	_____
D.) OTHER ITEMS (LANDSLIDE AREAS, SPRINGS, EROSION PROBLEMS, ETC.):	
_____	_____
_____	_____
_____	_____
3.) REQUEST ADDITIONAL SOILS INFORMATION FROM HELENA CORE DRILL, GEOTECHNICAL, ETC.:	
_____	_____
_____	_____
_____	_____

sak:soilsnew

APPENDIX D - SURFACING DESIGN INFORMATION

The following tables and charts are examples used by the surfacing designer. The information is mainly from the "MDT Pavement Design Manual, 1991" which was written by the MDT Materials Bureau.

DATA SHEET 1

Daily 18 KIP Equivalent Axle Load Computation

Project No: F 20-1(4)1 Date: 26-Sep-88
Description: Glendive - North Pavement Type: Rigid
Flexible:X

Current AADT: 1680 Current AADT: 1990 Lane Design
Design AADT: 2050 Design AADT: 2010 Factor: 100%

Vehicle Type	% of Type	Current ADT	Design Year ADT	Mean Year ADT	Directional ADT	Design Lane ADT	18K Equiv Rate Fac	Mean Year ADL
Pass. Car		0	0.0	0.0	0.0	0.0		0.00
Pickup & Van		0	0.0	0.0	0.0	0.0		0.00
Busses		0	0.0	0.0	0.0	0.0		0.00
2 Axle/4 Tire		0	0.0	0.0	0.0	0.0		0.00
2 Axle/6 Tire	4.4	73.92	90.2	82.1	41.0	41.0	0.351	14.40
3 Axle S.U.	0.9	15.12	18.5	16.8	8.4	8.4	0.527	4.42
4 Axle or More S.U.		0	0.0	0.0	0.0	0.0		0.00
3 Axle Semi		0	0.0	0.0	0.0	0.0		0.00
4 Axle Semi	0.7	11.76	14.4	13.1	6.5	6.5	0.545	3.56
5 Axle Semi	5.9	99.12	121.0	110.0	55.0	55.0	1.504	82.75
6 Axle Semi	0.5	8.4	10.3	9.3	4.7	4.7	1.640	7.65
3 Axle Truck/Full Tr		0	0.0	0.0	0.0	0.0		0.00
4 Axle Truck/Full Tr		0	0.0	0.0	0.0	0.0		0.00
5 Axle Truck/Full Tr	0.2	3.36	4.1	3.7	1.9	1.9	2.102	3.92
6 Axle Truck/Full Tr	2.6	43.68	53.3	48.5	24.2	24.2	1.708	41.41
5 Axle Tr/Semi/Full	1.3	21.84	26.7	24.2	12.1	12.1	1.220	14.79
6 Axle Tr/Semi/Full		0	0.0	0.0	0.0	0.0		0.00
7 Axle Tr/Semi/Full	0.5	8.4	10.3	9.3	4.7	4.7	1.618	7.54
8 Axle Tr/Semi/Full	0.5	8.4	10.3	9.3	4.7	4.7	1.636	7.63
7 Axle Triple Tr.		0	0.0	0.0	0.0	0.0		0.00
8 Axle Triple Tr.		0	0.0	0.0	0.0	0.0		0.00
TOTAL VALUES	17.5							188.07

The Average Daily 18Kip EAL for a 20-year Design Life is 188.07

Design 18Kip Equivalent Axle Loads = 1,372,886

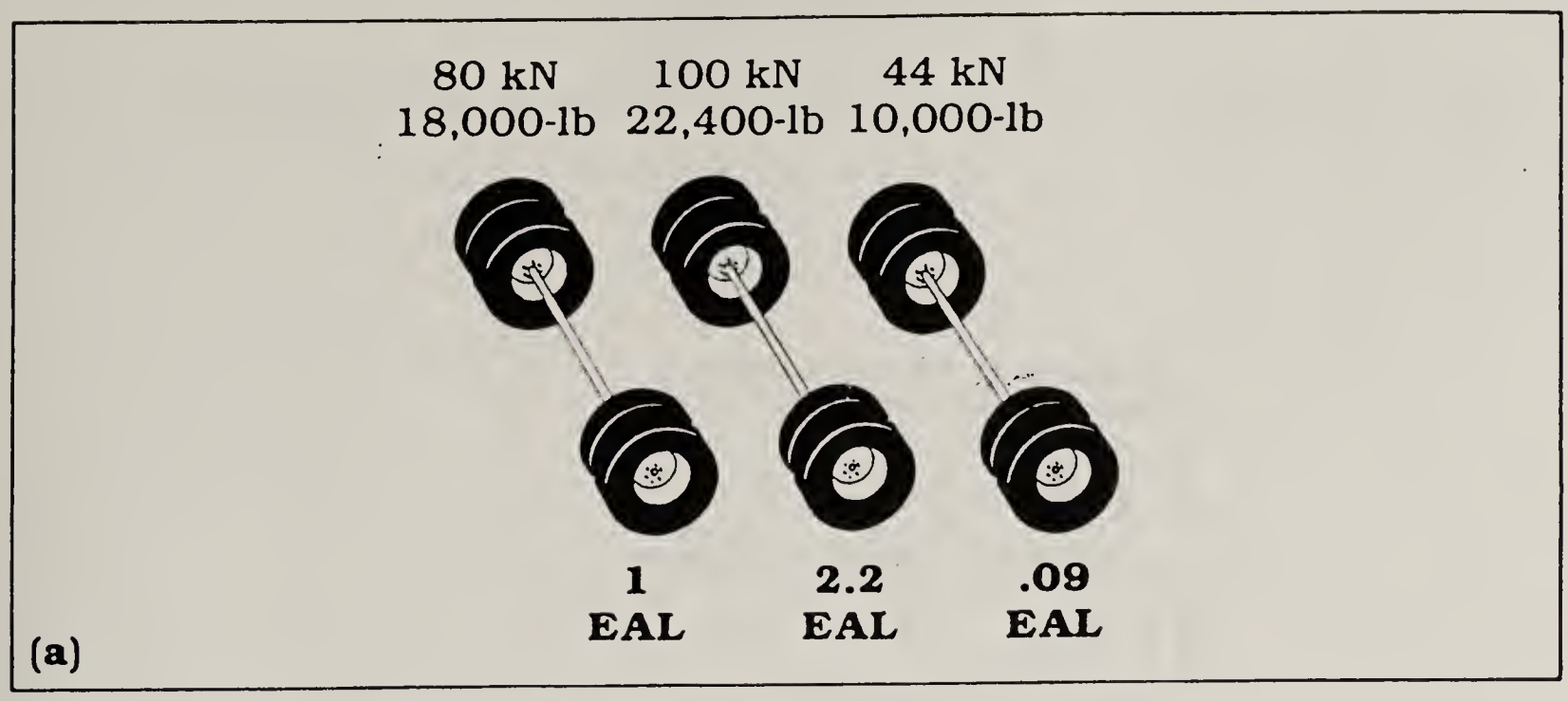
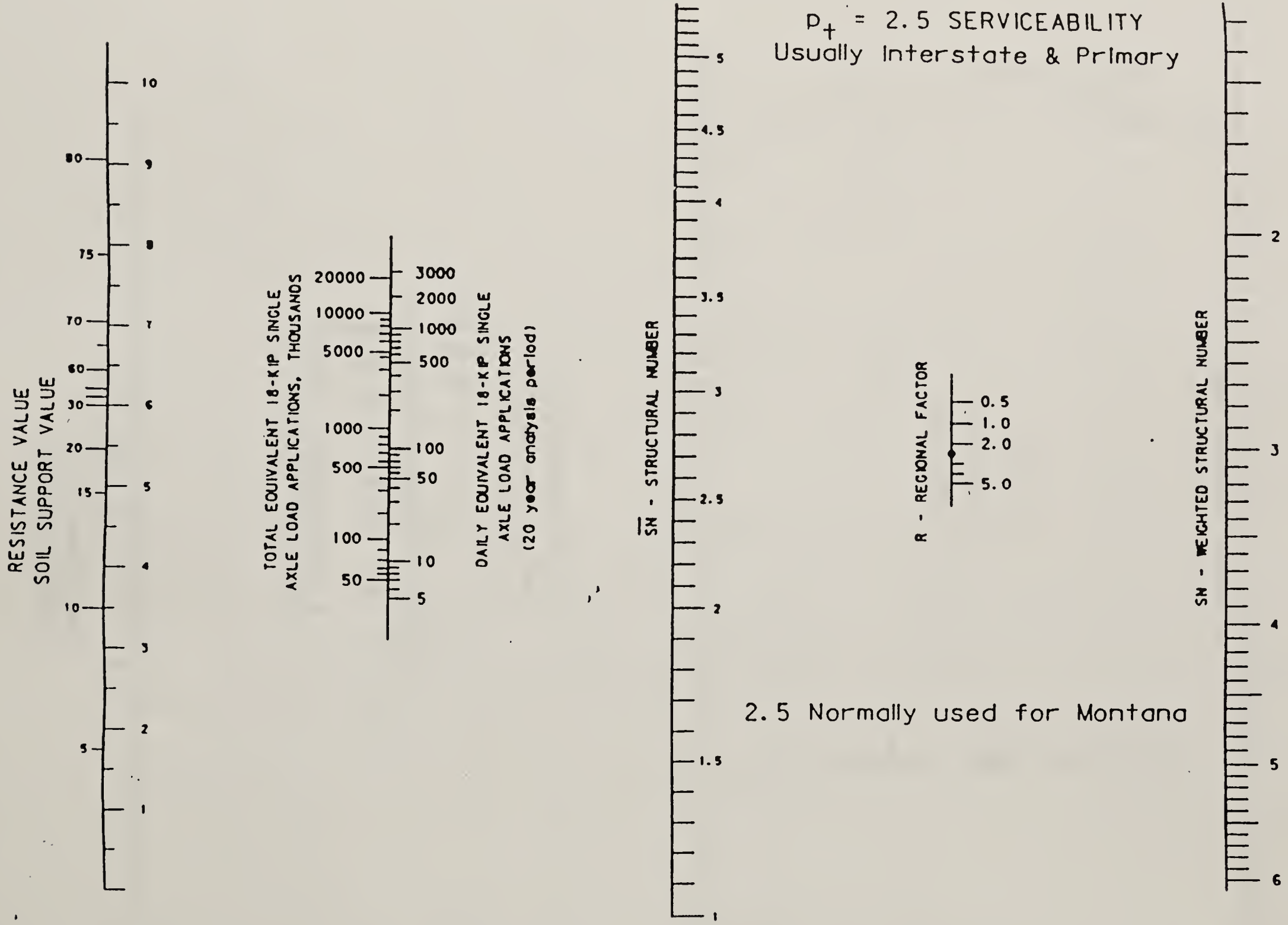


Figure IV-1. Load Equivalency Factors



p_t = 2.5 SERVICEABILITY
Usually Interstate & Primary

2.5 Normally used for Montana

FLEXIBLE PAVEMENTS DESIGN CHART

20 YEAR TRAFFIC ANALYSIS

FLEXIBLE PAVEMENTS DESIGN CHART

20 YEAR TRAFFIC ANALYSIS

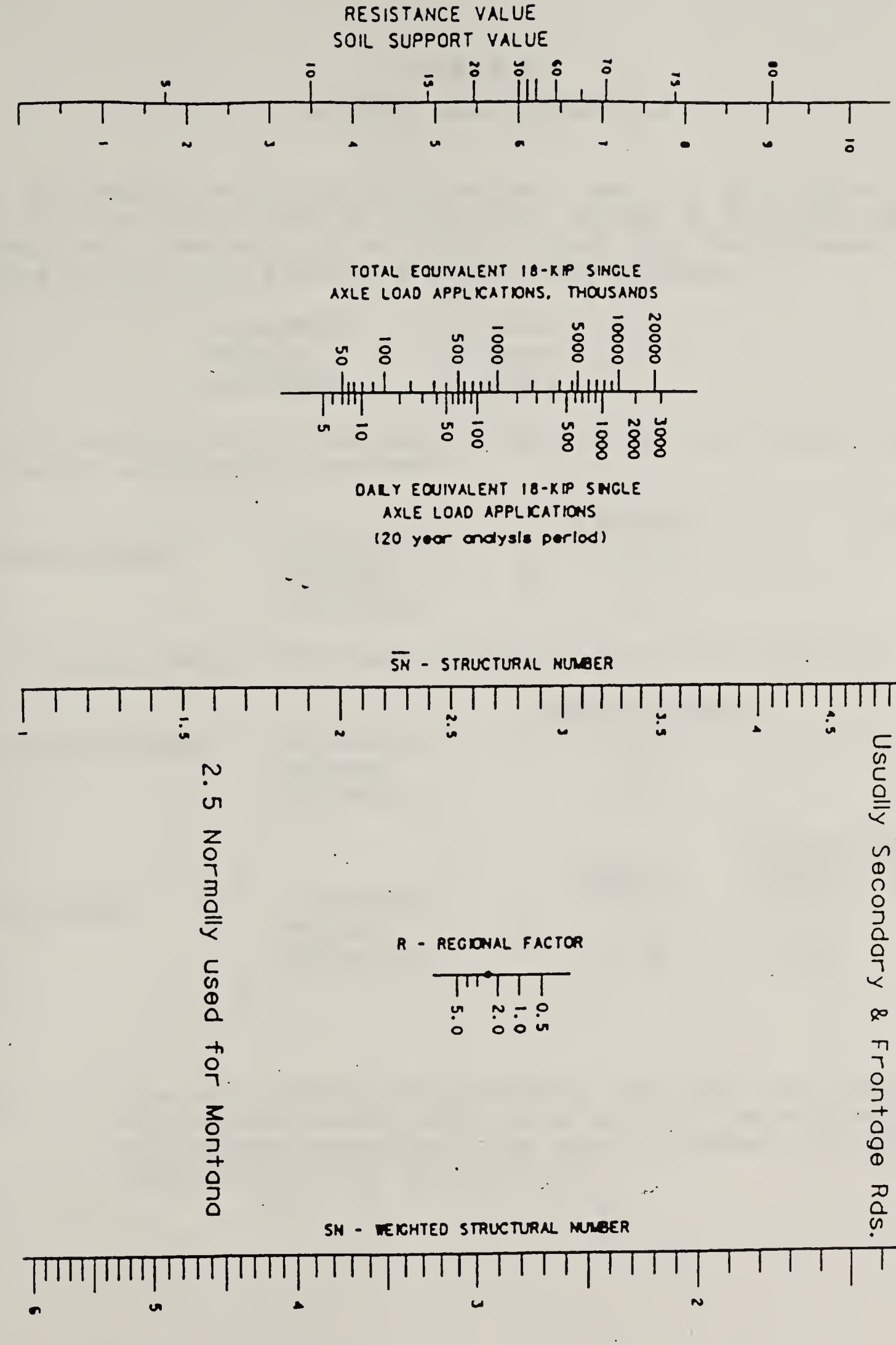


TABLE 3-1

MINIMUM DESIGN CRITERIA

The following are the minimum design lives for which the Pavement Analysis Unit will design. These are based on the FHWA PMS guidelines. However, it should be noted that the Pavement Analysis Unit will generally design for 20-years.

INTERSTATE	8 years
PRIMARY	8 years
SECONDARY	5 years

The following are the minimum thicknesses of the various types of surfacing materials to be used.

			ASPHALT	CONCRETE
SURFACE COURSE	INTERSTATE	=	0.40′	8"
	PRIMARY	=	0.30′	7"
	SECONDARY	=	0.30′	7"

The minimum design thickness of PMBS to be place is 0.15′.

			CRUSHED GRAVEL
LEVELING COURSE	INTERSTATE	=	0.20′
	PRIMARY	=	0.15′
	SECONDARY	=	0.15′

			ASPHALT	TREATED SOILS	CRUSHED GRAVEL
BASE COURSE	INTERSTATE	=	0.35′	0.35′	0.50′
	PRIMARY	=	0.35′	0.35′	0.50′
	SECONDARY	=	0.35′	0.35′	0.50′

Note: The only minimum requirements that will be placed on off-system bridge approaches is that the surfacing on the bridge approaches must meet or exceed the surfacing structure of the existing PTW.

TABLE 3-2

SURFACING COEFFICIENTS FOR STRUCTURAL COMPONENTS

SURFACING COURSES	R-Value 70> Per Inch	R-Value 60-70 Per Inch	R-Value 70> Per Foot	R-Value 60-70 Per Foot
Plant Mix Grade A	0.33	0.30	4.0	3.6
Plant Mix Grade B	0.33	0.30	4.0	3.6
Plant Mix Grade C	0.31	0.28	3.7	3.4
Road Mix	0.20	0.18	2.4	2.2
Milled Asphaltic Material	0.16	0.14	1.9	1.7
Crushed Gravel	0.12	0.10	1.4	1.2
TREATED BASE COURSES				
Bituminous Stabilized	0.20	0.18	2.4	2.2
Cement Treated +400 psi at 7 Days	0.20	0.18	2.4	2.2
Cement Treated -400 psi at 7 Days	0.15	0.14	1.8	1.7
Lime Treated	0.15	0.14	1.8	1.7
GRAVEL BASE COURSES				
Crushed Gravel 1½" Max.	0.12	0.10	1.4	1.2
Crushed Gravel over 1½"	0.11	0.09	1.3	1.1
Selected Surfacing	0.10	0.08	1.2	1.0
Special Borrow	0.07	0.06	0.8	0.7
Sand Surfacing	0.05	0.05	0.6	0.6

NOTE: The R-Values referred to in the headings are the general R-Values of surfacing sources found in the area of the project being designed.

TABLE 5-2

REDUCTION FACTORS FOR EXISTING PAVEMENT

Description of Existing Pavement[1]	Reduction Factor (RF)
Pavement surface exhibits appreciable cracking and crack patterns, little or no spalling along the cracks, some wheel path deformation, and essentially stable.	0.5-0.7
Pavement surface exhibits some fine cracking, small intermittent cracking patterns, and slight deformation in the wheel paths, and obviously stable.	0.7-0.9
Pavement surface generally uncracked, little or no deformation in the wheel paths, and stable.	0.9-1.0

1 This is based on a visual survey of the type and extent of distress. If the pavement distress and deterioration is worse than described in the table, consideration should be made for the removal and reconstruction of the pavement.

AGGREGATE THICKNESS DESIGN CHART
FOR AGGREGATE SURFACED ROADS

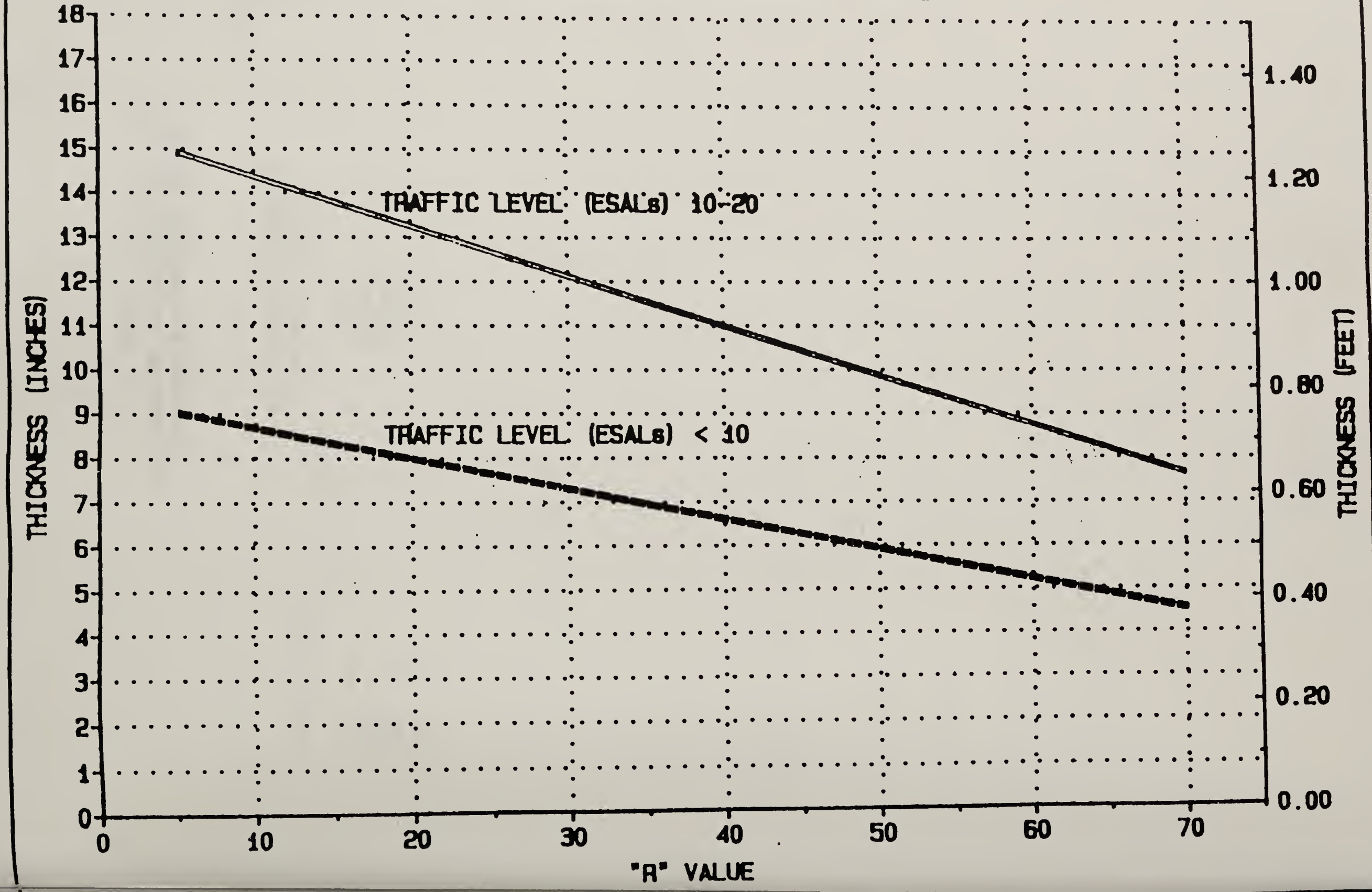


Table 3.4
AGGREGATE SPECIFICATION FOR AGGREGATE SURFACED ROADS

Sieve Size	Percentage Passing Nominal Maximum	Plasticity Index Range
3/4 in.	100	3-10
No. 4	40-80	
No. 10	25-60	
No. 200	5-20	

Montana Department of Transportation

Memorandum

To: James A. Walther, P.E.
Materials Engineer

Attn: Surfacing Design

From:

Date:

Subject: Project Number
Project Name

Please provide a surfacing typical section for the _____ _____ project. The District Materials Group will be submitting R-value samples in the near future for your use.

The latest traffic data is attached.

Please contact _____ at _____ if we can be of future assistance.

mjb:SURFREQ

Attachment

cc: District Engineer
D.S. Johnson, Helena
C.S. Peil, Helena
R.E. Williams, Helena
Design File

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